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MATHEMATICS.—*Intuitive and descriptive geometry of function space: Tensors and bi-vectors.*[1] BRUCE LONGTIN, Department of Chemistry, Illinois Institute of Technology, and MERLE RANDALL, Department of Chemistry, University of California. (Communicated by FREDERICK D. ROSSINI.)

In the preceding papers[2,3] a graphical method of representing the geometry of function space was developed. The method depended principally upon a vector geometry. The present paper briefly discusses the geometrical representation of more complex multiple numbers.

BI-VECTORS

The representation of an ordinary *real vector* was made by subdividing an interval Δ into n equal parts; in the center of each interval an ordinate was erected equal to the magnitude of one of the n components. When any component is a complex number, (u_j+iv_j), it is represented by an Argand diagram, rather than by a single coordinate. Hence, a bi-vector, $\mathbf{u}+i\mathbf{v}$, is to be represented by erecting the Argand diagram for each component at the center of one of the subintervals of Δ.

In Fig. 1 the bi-vector $(2+i3, 1-i, i, 2)$ is shown. The four Argand diagrams are arranged along the axis of indices with their real axes vertical and their imaginary vertices horizontal. The real and imaginary axes could have been interchanged. The particular choice was made in order that the diagram may reduce directly to the simple real vector diagram when the imaginary components vanish. As in the simple case, the four points representing the four components are joined by a single broken line to indicate that they belong to the same bi-vector.

In the case of an infinite number of dimensions, the components (u_j+iv_j) become in the limit values of the complex function, $\phi(x)=u(x)+iv(x)$. If the functions $u(x)$ and $v(x)$ are continuous, the con-

[1] Clerical assistance of the Works Progress Administration is gratefully acknowledged, O.P. 165-1-08-73. (Unit C-2.) Received July 22, 1941.
[2] RANDALL and LONGTIN. Journ. Wash. Acad. Sci. 31: 421–431, 453–466. 1941.
[3] LONGTIN and RANDALL. Journ. Wash. Acad. Sci. 31: 441–453. 1941.

necting broken line of Fig. 1 becomes the continuous space curve of Fig. 2. The Argand vectors representing the individual components of ϕ then generate a *helicoidal* surface terminated by the X axis and this space curve. If the functions $u(x)$ and $v(x)$ are not continuous, the space curve may be extremely discontinuous, consisting only of a scattering of points.

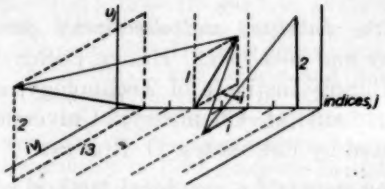

Fig. 1.—A 4-component bi-vector in the proposed representation.

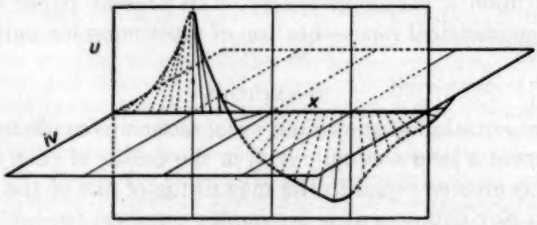

Fig. 2.—An n-component bi-vector in function space.

With the use of this representation of a bi-vector, all the graphical results obtained for real vectors may be repeated. It is necessary only to give due consideration to the presence of the imaginary terms. For example, the sum of two bi-vectors, $\phi+\psi$, is a bi-vector, represented by the function $(\phi(x)+\psi(x)=(u_\phi(x)+u_\psi(x))+i(v_\phi(x)+v_\psi(x))$. This function is obtained graphically by adding the Argand vector of $\psi(x)$ to that of $\phi(x)$ vectorially for each value of x. This single example is sufficient to indicate the general plan of development.

AN ALTERNATIVE METHOD OF REPRESENTING BI-VECTORS

The Argand diagram by which the bi-vector, $(\mathbf{u}+i\mathbf{v})$, was represented in Figs. 1 and 2 might equally well be represented by plotting **u**-components as in the upper part of Fig. 3 and the **v**-components in the lower part of the diagram. It is to be understood that the lines for the **u**- and **v**-components erected at the center of the several subintervals of Δ must be considered as tied together by the restriction that they are to be considered as being projections corresponding to the plane of Fig. 1 at a given index j.

Thus, while all the propositions that we have given for real vectors may be repeated for either the real component (upper half of Fig. 3) or the imaginary component (lower half of Fig. 3) the arrangement of coordinates chosen for the real component must be rigidly adherred to for the imaginary component. We thus simultaneously apply all the theorems previously developed but apply the restriction that any particular arrangement of groups chosen for the one component must also be used for the second or imaginary component of the figure.

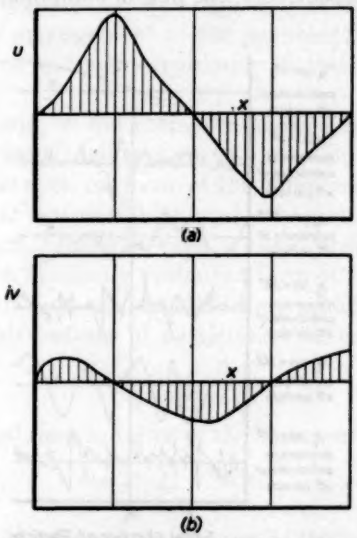

Fig. 3.—Alternative method of representing bi-vectors. (a) Real part; (b) imaginary part of Argand diagram.

REPRESENTATION OF PHASE SPACE FOR n PARTICLES

In statistical mechanics, the concept of a phase space composed of three positional and three momentum coordinates for each of n particles has proved useful. The coordinates of such a phase space may be represented graphically by a method closely analogous to that used in representing bi-vectors.

The phase coordinates to be represented are three position coordinates, $q_1(x)$, $q_2(x)$, $q_3(x)$, and three momentum coordinates, $p_1(x)$, $p_2(x)$, $p_3(x)$, of the x^{th} particle, for n such particles. The coordinates of each particle constitute the components of a 6-dimensional vector. In 7-dimensional space, one might subdivide the X-axis into small intervals, each assigned to a particular particle. At the center of each

interval, one would then erect the 6-dimensional vector which represents the phase coordinates of that particular particle.

In practice, it is necessary to use projections of the 7-dimensional figure. It is sufficient to use three solid diagrams, each corresponding to one of the three dimensions of physical space. Each diagram would be similar to Fig. 1 (or to Fig. 2 if the number of particles is infinite). In the first, the coordinates $q_1(x)$ and $p_1(x)$ would replace the real and imaginary parts, respectively, of the bi-vector. The second and third would represent, respectively, the pair of components $q_2(x)$, $p_2(x)$, and the pair $q_3(x)$, $p_3(x)$.

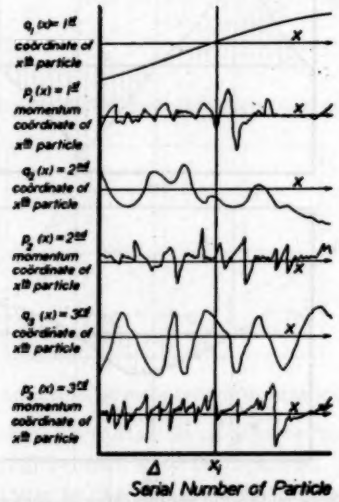

Fig. 4.—A $6n$ diagram showing the coordinates and phase components of a highly improbable state of a system of n particles.

It is, of course, more convenient to use six plane views of the 7-dimensional figure, as is done in Fig. 4. In each view, one of the coordinates $q_1(x)$, $q_2(x)$, $q_3(x)$, $p_1(x)$, $p_2(x)$ and $p_3(x)$, is plotted against the variable x, which labels the particular particle to which the coordinate belongs.

It is like a 3-dimensional Argand diagram that uses a 2-dimensional vector for each component of the bi-vector. But here we need a 6-dimensional *vector* for each particle. Each 6-dimensional vector might be considered as one sextuple component of a sextuple vector in n-space, as compared to the n double components of a bi-vector. By a sextuple vector, we mean one having six sets of components, just as a bi-vector has two sets of components (real and imaginary).

Concerning the appearance of the phase space diagram, we can not presume that the physical system has at the present instant a distribution of coordinates and moments that corresponds to the statistically most probable distribution. Actually it may never have this distribution.

Any set of six curves that we might draw represents a possible configuration of the system. The more regular curves represent quite improbable configurations, with unusually high total energy, but nevertheless possible configurations. The regularity of the curves necessarily implies an orderly arrangement of the particles in space along some smooth space-curve and some regularity in the distribution of momenta.

On the other hand, if the momenta showed Maxwell-Boltzmann distribution, each would follow a curve $q_i(x) = (\ln x)^{1/2}/x$, if arranged monotonically. However, only one of the components at a time could be so arranged. The rest would be randomly permuted arrangements of the same function. Similarly, each of the coordinates, $q_i(x)$, would be represented by a randomly permuted form of the function $q_i(x) = b+cx$, in the absence of any special forces which favor other than random spatial distributions of particles. A fuller discussion will be given later.

TENSORS

A tensor of second rank in terms of the base vectors[4] $\mathbf{e}_i^0$ is

$$\mathbf{A}_{(2)} = \sum_{i,j} A^{ij}\mathbf{e}_i^0\mathbf{e}_j^0. \tag{1}$$

Furthermore, it is invariant to a change in the base vector system. Hence it must be expressed in terms of the reduced base vector system as[5]

$$\mathbf{A}_{(2)} = \sum_{i,j} A'^{ij}\mathbf{e}_i'\mathbf{e}_j', \tag{2}$$

where

$$A'^{ij} = A^{ij}/(\Delta/n). \tag{3}$$

A tensor is sometimes represented graphically by the invariant quadric surface, $\mathbf{v}\cdot\mathbf{A}_{(2)}\cdot\mathbf{v}=1$, associated with it. This representation may be extended to n dimensions, and is useful in visualizing the concept of the *eigenvectors* of a tensor. However, a more generally useful representation may be obtained by considering the matrix, (A'^{ij}), of the tensor $\mathbf{A}_{(2)}$.

[4] i and j are here used merely as indices, not as $(-1)^{1/2}$.

[5] Cf. KOWALEWSKI, G. *Ueber Funktionenräume*, Sitz. Akad. Wiss. Wien 120 (2a:1): 77. 1911.

The matrix is customarily represented by subdividing a large square into n^2 equal small squares, in each of which an appropriate component, A'^{ij}, of the tensor is entered. The component A'^{ij} is entered in the i^{th} row and j^{th} column of the large square. Fig. 5 is the representation of a matrix associated with a 4-dimensional space. If we

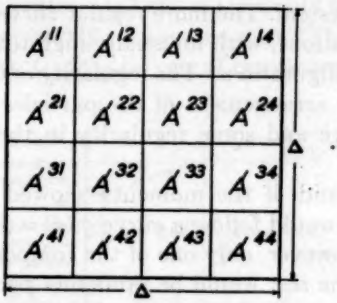

Fig. 5.—Matrix of 2-rank and 4-order.

imagine that each of the small squares has associated with it the appropriate base vector dyad $\mathbf{e}_i'\mathbf{e}_j'$, then Fig. 5 is a representation of the tensor.

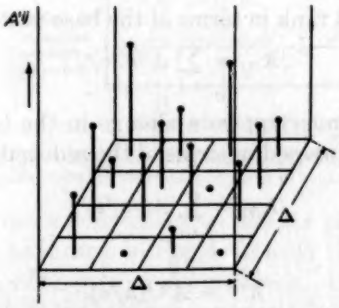

Fig. 6.—The proposed representation of the matrix of Fig. 5.

In analogy to the representation of a vector, the matrix representation may be made completely geometric. In Fig. 6 an ordinate has been erected at the center of each of the squares of Fig. 5. The ordinate erected in any particular square is numerically equal to the value A'^{ij} associated with that square in Fig. 5. In order to tie together all the points in the diagram of a single tensor, we may construct a tightly stretched surface (e.g., the surface of least area) between these

points. This surface corresponds to the broken line used in the representation of a vector.

As the number, n, of dimensions of the space is increased, the square of constant dimensions $\Delta \times \Delta$ is subdivided into smaller and smaller squares of dimensions $(\Delta/n) \times (\Delta/n)$. In the limit the component A'^{ij} is found in a square whose center has the coordinates $(a+i\Delta/n)$ and $(b+j\Delta/n)$, respectively. The infinite matrix (A'^{ij}) is, in the limit, represented by a function $A(x, y)$, in which x and y are the limits of $(a+i\Delta/n)$ and $(b+j\Delta/n)$ and are defined only in the intervals $(a, a+\Delta)$ and $(b, b+\Delta)$, respectively. The function $A(x, y)$ may be continuous or so discontinuous that it is represented graphically by a scattering of points rather than a continuous surface.

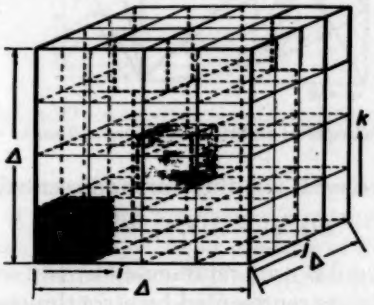

Fig. 7.—Representation of a matrix of 3-rank and 4-order.

A tensor, $\mathbf{A}_{(3)}$, of third rank is an invariant linear form in the base vector triads $\mathbf{e}_i^\circ \mathbf{e}_j^\circ \mathbf{e}_k^\circ$. Its matrix is of the form (A^{ijk}). Expressed in terms of the reduced base vector system its matrix is (A'^{ijk}), where A'^{ijk} is equal to $A^{ijk}(\Delta/n)^{-3/2}$. The matrix may be represented by dividing a cube into n^3 small equal cubes. Each number A'^{ijk} is then inscribed at the center of the appropriate cube (the i^{th} cube in the j^{th} row of the k^{th} layer). The representation becomes more graphic if each small cube is considered to have a mass density equal to the appropriate value of A'^{ijk}. Such a representation is shown in Fig. 7.

In the limit, as n increases, the matrix (A'^{ijk}) is represented by a function $A(x,y,z)$, which is the density at a point (x,y,z) within the cube. If each elementary cube in the mass distribution is considered to have a base vector triad $\mathbf{e}_i' \mathbf{e}_j' \mathbf{e}_k'$ associated with it, then the mass distribution within the large cube represents the tensor $\mathbf{A}_{(3)}$. The concept that $\mathbf{A}_{(3)}$ is represented by a function $A(x,y,z)$ is readily generalized to tensors of higher rank,[4] but the geometrical picture can not easily be carried further.

TENSOR ADDITION

The sum of two tensors of the same rank is defined as a tensor,

$$\mathbf{C}_{(2)} = \mathbf{A}_{(2)} + \mathbf{B}_{(2)};$$
$$C^{ij} = A^{ij} + B^{ij}. \tag{4}$$

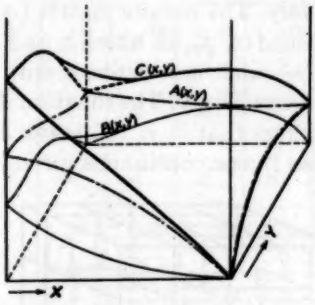

Fig. 8.—Graphical addition of tensors of 2-rank, $\propto$-order.

In the limit the tensor $\mathbf{C}_{(2)}$ is therefore represented by a function,

$$C(x, y) = A(x, y) + B(x, y). \tag{5}$$

If the tensors $\mathbf{A}_{(2)}$ and $\mathbf{B}_{(2)}$ are represented by two continuous surfaces, then their sum, $\mathbf{C}_{(2)}$, is represented by a continuous surface whose ordinates are sums of the corresponding ordinates of the surfaces representing $\mathbf{A}_{(2)}$ and $\mathbf{B}_{(2)}$.

VECTOR–TENSOR DOT PRODUCT

The dot product $\mathbf{A}_{(2)} \cdot \mathbf{v}$ is defined in terms of the reduced base vector system as the vector

$$\mathbf{u} = \mathbf{A}_{(2)} \cdot \mathbf{v} = \sum_{i,j} A'^{ij} \mathbf{e}_i' \mathbf{e}_j' \cdot \mathbf{v} = \left[\sum_j A'^{ij} v_j (\Delta/n) \right] \mathbf{e}_i. \tag{6}$$

In the limit of a function space, this becomes

$$\mathbf{u} = \mathbf{A}_{(2)} \cdot \mathbf{v} = \sum_j \left[\int_\Delta A(x, y) v(y) dy \right] \mathbf{e}_x. \tag{7}$$

The transformed vector is represented in the function-space diagram by the function

$$u(x) = \int_\Delta A(x, y)\, v(y) dy. \tag{8}$$

In Fig. 9 the graphical construction is shown by which the transformed vector may be obtained. For each value of x the tensor traces out a plane curve $A(x_1,y)$. The ordinates of this curve are each multiplied[6] by the corresponding ordinate of the curve $v(y)$ and the area under the resulting curve is taken as the x_1 component of the curve $u(x)$.

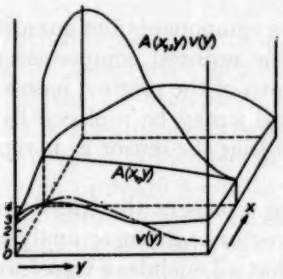

Fig. 9.—A graphical construction for obtaining the dot product of a ∞-vector and a tensor of 2-rank, ∞-order.

An example of the use of a product of the form $\mathbf{A}_{(2)} \cdot \mathbf{v}$ is to be found in the calculation of the vapor pressure of a petroleum fraction from its true boiling point assay. The vapor pressure of a pure hydrocarbon is a function of the temperature T, and of the true boiling point θ (i.e., is different for each hydrocarbon and is correlated with the true boiling point of the hydrocarbon). It may be expressed as $P(T,\theta)$. Suppose the mol fraction of hydrocarbons whose true boiling points lie in the range $(\theta,\ \theta+d\theta)$ is $x(\theta)d\theta$ in a particular mixture. Then Raoult's law gives $x(\theta)P(T,\ \theta)d\theta$ as the vapor pressure of this particular group of hydrocarbons. The total vapor pressure of the mixture is $\int x(\theta)P(T,\theta)d\theta$. Hence the total vapor pressure may be expressed as the vector tensor product, $\mathbf{P} \cdot \mathbf{x}$, and is a function of the temperature at which it is measured.

Function-space tensor operations in the form of equation 8, have been studied extensively. Equation 8 defines the Fredholm transformation of $v(y)$, which forms the basis of the Fredholm theory of integral equations.[7] Having obtained the geometrical interpretation, we need not carry the discussion further in detail. The large number of analytical results obtained in the theory of Fredholm equations may be easily given a geometrical interpretation in terms of this diagram.

[6] See RANDALL and LONGTIN. Ind. Eng. Chem., for graphical methods of carrying out this multiplication. To be published.

[7] FREDHOLM. Proc. Swedish Acad. 57. 1900; Acta Mathematica 27. 1903.

TRANSFORMATION OF COORDINATES

The transformation from one system of coordinate axes to a second was expressed by equation 22 of the second paper of this series.[3] Comparison of this equation with equation 7 shows that the transformation may be represented as a tensor operation,

$$\mathbf{v}' = \mathbf{E}' \cdot \mathbf{v}. \tag{9}$$

The tensor $\mathbf{E}'$ has as its components the quantities $e_{\lambda i}'$, each of which is the magnitude of the reduced component of a new base vector $\mathbf{e}_\lambda{}^\circ$ in the direction of one of the original base vectors, $\mathbf{e}_i$. In function space, the indices λ and i may be replaced by continuous variables ξ and x, with the result that the tensor $\mathbf{E}'$ is represented by the function $e(\xi, x)'$.

The use of tensors to represent the transformations of coordinates is well known in the vector and tensor analysis of ordinary 3-space. Delsarte[8] has shown that all euclidean transformations of coordinates in function space are special cases of the Fredholm operator, which is the most general form of the tensor operation. Thus the graphical methods of representing and operating with tensors which are presented above may be used in all of the transformations which are ordinarily necessary in obtaining auxiliary views of function space figures. They thus play an important role in the descriptive geometry of function space.

In the descriptive geometry of every-day experience, perspective projections are often useful. They may be obtained by means of what is known as a projective transformation of coordinates. The most general transformation of this type is expressed by the equation

$$\mathbf{v}' = \mathbf{E} \cdot (\mathbf{v} - \mathbf{a}) / [b + \mathbf{c} \cdot \mathbf{E}(\mathbf{v} - \mathbf{a})], \tag{10}$$

in which b is a scalar, $\mathbf{a}$ and $\mathbf{c}$ are vectors, and $\mathbf{E}$ is a tensor, all being constants.

If the constant b is zero, the transformation projects function space onto a plane at a distance $1/|\mathbf{E} \cdot \mathbf{c}|$ from the point of view. The point of view is located at the end of the vector $\mathbf{a}$, while the line of sight is parallel to the vector $\mathbf{c}$ (i.e., the projection plane perpendicular to $\mathbf{c}$. If b were not zero, the same perspective view would be obtained by taking an auxiliary view of the transformed diagram, parallel to the vector $\mathbf{c}$. The mathematical properties of such transformations in function space have been studied by Dines.[9]

[8] DELSARTE. Compt. Rend. 186: 415, 1095. 1928; Ann. Fac. Sci. Toulouse [3] 20: 47. 1928; Rend. Circ. Mat. Palermo 53: 135. 1929.
[9] DINES, L. L. Trans. Amer. Math. Soc. 20: 45. 1919.

SUMMARY

An ordinary function space vector is a quantity having a singly infinite number of components. In addition to these, there are other types in which the components naturally separate into a finite number of sets such that corresponding to each component of a particular set there is one and only one component in each of the other sets. Examples of this type are bi-vectors and phase-space coordinates. The representation of any such composite vector is a generalization of the method here presented for bi-vectors, which consist in constructing a function space vector diagram for each set of components.

When the number of sets of components becomes infinite, the quantity becomes the function-space equivalent of a matrix. A matrix is represented by erecting an ordinate equal to the magnitude of the matrix component at the center of each square in rectangular array ordinarily used to represent the matrix. The representation of a function-space matrix is obtained by passing to the limit of an infinite number of squares contained within a rectangle of fixed dimensions. This results in representing the matrix by a function of two variables.

The tensor, which is a special type of matrix, is useful as an operator in obtaining ordinary and perspective projections of function space figures. It is, therefore, of particular importance in more advanced studies of the descriptive geometry of function space.

GEOPHYSICS.—*Geothermal gradient at Grass Valley, Calif.: A revision with a note on the flow of heat.*[1] H. CECIL SPICER, U. S. Geological Survey. (Communicated by R. C. WELLS.)

The results presented herein are offered primarily as a revision of the computations that the writer made for W. D. Johnston, Jr.,[2] of temperature measurements made in the mines near Grass Valley, Calif. These results were also included in another recent publication.[3] A cursory reading of the later paper indicated some discrepancies, and in a subsequent study of the maps, text, and figure (fig. 1 of reference 2; fig. 8 of reference 3) the differences were located.

The 1,100 foot level of the Empire mine, altitude 2,200 feet, which is located at an average depth of approximately 300 feet below the

[1] Published by permission of the Director, U. S. Geological Survey. Received August 9, 1941.

[2] JOHNSTON, W. D., Jr. *Geothermal gradient at Grass Valley, California.* Journ. Washington Acad. Sci. **22** (10): 267–271. 1932; *Geothermal gradient of the Mother Lode belt, California.* Journ. Washington Acad. Sci. **22** (14): 389–393. 1932.

[3] JOHNSTON, W. D., Jr. *The gold quartz veins of Grass Valley, California.* U. S. Geol. Survey Prof. Paper **194**: 21–22. 1940.

surface was perhaps improperly chosen as the reference point for the earlier computations. Plate 35, reference 3, contains an error of altitude for the Empire 2,700 level; where the digits have been reversed so that the elevation should read 1,527 feet instead of 1,257 feet. This same level is designated the 2,200 at one place on the figure and is inconsistent with the two other 2,700 figures that are correct. However, these typographical errors do not change the computed results and are pointed out only in order that the altitudes, levels, and depths will be consistent in the revised results. Two other large differences in depth will be noted on comparing Table 1 of this paper with the earlier results; namely, Empire 3,400 and North Star 8,700 levels. Mine level altitudes supplied by W. D. Johnston, Jr., have taken the place of former figures given for these observations. Other minor differences between the depths in the two sets of results, have been disregarded.

A mean altitude of the ground surface above the included mine workings was obtained from the topographic map of the area,[3] and this altitude was used as the reference point for the present computations. This change of reference to a point 292 feet above the earlier

TABLE 1.—TEMPERATURE GRADIENT AT THE EMPIRE-STAR MINE, NEVADA COUNTY, CALIF.[1]

Mine	Mine level	Altitude	Depth[2]		Observed temperatures		305–972 feet		305–3715 feet	
							Comp. temp.	Obs. minus comp.	Comp. temp.	Obs. minus comp.
		Feet	*Meters*	*Feet*	°C.	°F.	°F.		°F.	
Empire	1100	+2195	93.0	305	12.4	54.4	54.2	+0.2	54.6	−0.2
Pennsylvania	1000	2052	136.6	448	12.9	55.3	55.1	+0.2	55.4	−0.1
New York Hill	600	1899	201.5	611	13.1	55.6	56.0	−0.4	56.3	−0.7
North Star	1900	1825	205.7	675	13.6	56.4	56.4	0.0	56.6	−0.2
Pennsylvania	1400	1780	219.5	720	13.5	56.3	56.6	−0.3	56.8	−0.5
Pennsylvania	1700	1571	283.2	929	14.3	57.7	57.8	−0.1	57.9	−0.2
Empire	2700	1528	296.3	972	14.7	58.5	58.1	+0.4	58.2	+0.3
Empire	3000	1361	347.2	1139	15.3	59.5	59.0	+0.5	59.0	+0.5
Pennsylvania	2100	1358	348.1	1142	15.1	59.1	59.0	+0.1	59.1	0.0
Pennsylvania	2400	1238	384.7	1262	15.5	59.9	59.7	+0.2	59.7	+0.2
Empire	3400	1174	404.2	1326	15.5	59.9	60.1	−0.2	60.0	−0.1
Empire	3800	965	467.9	1535	16.6	61.8	61.3	+0.5	61.1	+0.7
Empire	4200	773	526.4	1727	17.2	62.9	62.4	+0.5	62.1	+0.8
Empire	4600	569	588.6	1931	17.4	63.3	63.6	−0.3	63.2	+0.1
Empire	5000	355	653.8	2145	17.9	64.3	64.8	−0.5	64.3	0.0
Empire	5400	+ 98	732.1	2402	19.0	66.2	66.3	−0.1	65.7	+0.5
Empire	5800	− 159	810.5	2659	19.5	67.1	67.7	−0.6	67.1	0.0
Empire	6200	− 414	888.2	2914	20.2	68.3	69.2	−0.9	68.4	−0.1
Empire	7000	− 928	1044.9	3428	21.6	70.8	72.1	−1.3	71.1	−0.3
North Star	8700	−1061	1085.4	3561	22.0	71.6	72.9	−1.3	71.8	−0.2
North Star	9000	−1215	1132.3	3715	22.4	72.3	73.8	−1.5	72.6	−0.3

[1] Observations made in 1930–31 by W. D. Johnston, Jr.

[2] Depth below mean altitude of ground surface above mine workings. Mean altitude 2,500 feet.

Constants by least squares[3]

305–972 feet	972–3715 feet	1931–2914 feet
$a = 52.50$	$a = 53.65$	$a = 53.41$
$b = 0.00573$	$b = 0.00505$	$b = 0.00516$
$1/b = 174.7$	$1/b = 198.2$	$1/b = 193.9$
$r = \pm 0.21$	$r = \pm 0.18$	$r = \pm 0.19$
$r_a = \pm 0.25$	$r_a = \pm 0.12$	$r_a = \pm 0.58$
$r_b = \pm 0.00036$	$r_b = \pm 0.00005$	$r_b = \pm 0.00024$
305–1931 feet	**1931–3715 feet**	**2402–3428 feet**
$a = 52.46$	$a = 53.79$	$a = 55.14$
$b = 0.00586$	$b = 0.00499$	$b = 0.00455$
$1/b = 170.7$	$1/b = 200.4$	$1/b = 220.0$
$r = \pm 0.23$	$r = \pm 0.13$	$r = \pm 0.10$
$r_a = \pm 0.15$	$r_a = \pm 0.21$	$r_a = \pm 0.36$
$r_b = \pm 0.00013$	$r_b = \pm 0.00007$	$r_b = \pm 0.00013$
305–2914 feet	**972–1931 feet**	**2914–3715 feet**
$a = 52.82$	$a = 53.09$	$a = 53.66$
$b = 0.00547$	$b = 0.00546$	$b = 0.00502$
$1/b = 182.9$	$1/b = 183.3$	$1/b = 199.2$
$r = \pm 0.25$	$r = \pm 0.21$	$r = \pm 0.07$
$r_a = \pm 0.13$	$r_a = \pm 0.35$	$r_a = \pm 0.38$
$r_b = \pm 0.00008$	$r_b = \pm 0.00025$	$r_b = \pm 0.00011$
305–3715 feet	**1535–2402 feet**	**305–3428 feet[4]**
$a = 53.03$	$a = 54.38$	$a = 53.38$
$b = 0.00528$	$b = 0.00478$	$b = 0.00518$
$1/b = 189.5$	$1/b = 209.1$	$1/b = 193.1$
$r = \pm 0.26$	$r = \pm 0.24$	$r = \pm 0.26$
$r_a = \pm 0.11$	$r_a = \pm 0.69$	$r_a = \pm 0.18$
$r_b = \pm 0.00006$	$r_b = \pm 0.00035$	$r_b = \pm 0.00009$

[3] °F./ft. × 1.82269 = °C./m.
[4] Observations in Empire–Star only.

computations causes the largest variation between the constants in the two computations. This change, however, places the reference point at the mean surface of the ground; the usual place of reference in earth temperature computations.

The same method was used to compute the constants in both instances; namely, the adjustment of a set of observations to a straight line by the method of least squares. The equation to be adjusted is

$$y = a + bx$$

in which

y = temperature at a point of observation.
a = computed annual mean temperature of the ground just below the surface.
b = geothermal gradient in degrees Fahrenheit per foot.
x = depth to an observed temperature.

$1/b$ = reciprocal geothermal gradient in feet per degree Fahrenheit.
r = probable error of an observed temperature y of weight unity.
r_a, r_b = probable errors of the computed constants a and b.
The computations are summarized in Table 1.

The constants for some intervals not given in the previous paper have been added to this table. A separate set of constants for the observations made in the Empire mine were computed so that a comparison could be made with the other results that contain observations in nearby or connected mine workings. By comparing the gradient of the 305–3,715 foot interval, in which all of the observations were used, with the one for the 305–3,428 foot interval in the Empire alone, the observations are shown to be very homogeneous, and, therefore, the observed temperatures in close-by mines are believed to be definitely related to those in the Empire.

The observed annual mean temperature agrees closely with the computed temperature just below the surface of the ground in these results as well as in the previous ones. For the 305–972 foot interval, the observed air temperature exceeds the soil temperature by 0.1° F.; and for the 305–3,715 foot interval the excess of soil temperature is 0.4° F. The latter figure doubtless expresses the true soil temperature. The value of a is the point of intersection between the computed temperature line and the temperature axis, and reference to Fig. 1 shows this relation. The observed annual mean temperatures at Nevada City and Grass Valley have also been included in this figure and may be compared to the computed results.

The revised depth–temperature relations retain the slight concavity toward the depth axis as previously pointed out by Johnston.[2,3] The values of the geothermal gradient b decrease with increasing depth, and this is the indicator for a depth–temperature relation to be concave toward the depth axis.

An additional point on the flow of heat toward the surface may be of interest. All the observations were made in granodiorite, according to Johnston,[3] except the New York Hill 600, Empire 1100, and the North Star 1900, which were in porphyrite and diabase. The Empire 1100 observation was about 50–75 feet above the contact of the granodiorite. Neither in situ or laboratory tests have been made on these particular rocks, but results of the proper magnitude may be calculated from published figures of the thermal conductivity of similar materials as well as from computed thermal conductivities of the rocks of the area.

Some values of experimentally determined thermal conductivities

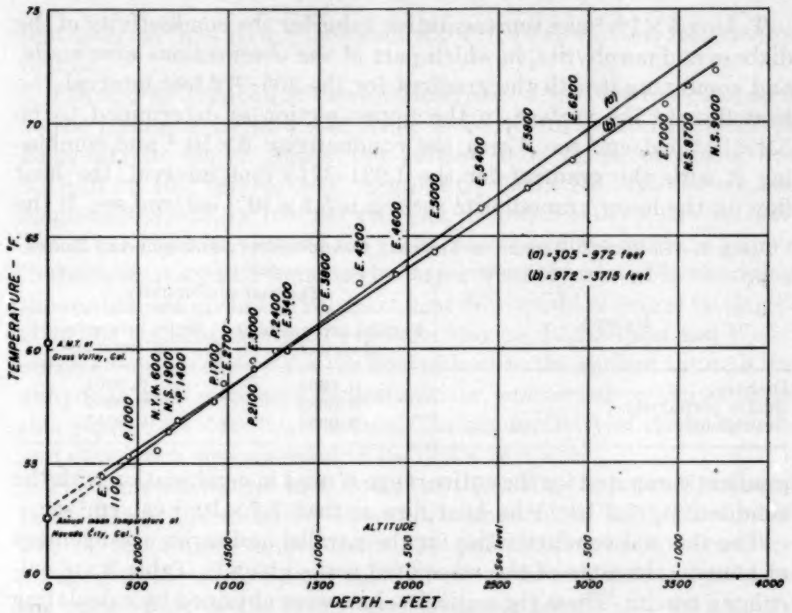

Fig. 1.—Depth–temperature relation, Empire–Star Mine, Grass Valley, Calif.

of rocks which are similar to those in the Grass Valley area are given in Table 2.

TABLE 2.—EXPERIMENTALLY DETERMINED VALUES OF THERMAL CONDUCTIVITY OF ASSOCIATED ROCKS

Material	Thermal conductivity		Authority
	Range $\times 10^3$	Mean $\times 10^3$	
Diabase	5.02–5.44	5.20	Birch and Clark[1]
Augite porphyrite			
Hornblende porphyrite	2.77–8.57	4.84	Tadokoro[2]
Porphyrite			
Quartz monzonite		7.56	Birch and Clark[1]
Granite	5.60–8.30	6.99	Birch and Clark[1]
Granite	4.19–6.01	5.23	Tadokoro[2]
Granite porphyry		5.7	I.C.T.[3]
Granite		8.1	Ingersoll and Zobel[4], Nancarrow[5]
Granodiorite		6.2	Interpolated from Birch and Clark[1] using granite and diabase

[1] BIRCH, F., and CLARK, H. *Thermal conductivity of rocks and its dependence upon temperature.* Amer. Journ. Sci. 238: 529–558, 613–635. 1940.

[2] TADOKORO, Y. *Determination of the thermal conductivity . . . of rocks.* Tôhoku Univ. Sci. Rep. 10: 339–410. 1921.

[3] *International critical tables.* McGraw-Hill Co., New York City.

[4] INGERSOLL, L. R., and ZOBEL, O. J. *Introduction to the mathematical theory of heat conduction.* Ginn & Co., New York City. (Out of print.)

[5] NANCARROW, H. A. *Thermal conductivities of rocks.* Proc. Phys. Soc. London 45: 447–467. 1933.

Taking 5×10^{-3} as a representative value for the conductivity of the diabase and porphyrite, in which part of the observations were made, and combining it with the gradient for the 305–972 foot interval, the heat flow to the surface in the upper section is determined to be 5.2×10^{-7} cal/cm² sec. Using the conductivity 6×10^{-3} and combining it with the gradient for the 1,931–3715 foot interval, the heat flow in the lower granodiorite section is 5.5×10^{-7} cal/cm² sec. If the

TABLE 3.—COMPUTED VALUES OF THERMAL CONDUCTIVITY OF ASSOCIATED ROCKS

Material	Thermal conductivity	
	Parallel arrangement of elements	Series arrangement of elements
Diabase	0.0081	0.0061
Quartz porphyrite	0.0082	0.0059
Granodiorite	0.0084	0.0057

gradient computed for the entire range is used in combination with the conductivity 6×10^{-3}, the heat flow is then 5.7×10^{-7} cal/cm² sec.

The thermal conductivities for the parallel and series arrangement of mineral elements of the associated rocks given in Table 3 are calculated results. These theoretical values were obtained by calculating the norms and/or modes of the rocks from the chemical analyses[4] given in reference 3, grouping the constituents having similar thermal properties and obtaining the conductivity of each group from the results given by Birch and Clark,[5] then substituting in the formulas for computing the thermal conductivity of aggregates having either series or parallel arrangement of mineral elements. The results for the series arrangement of mineral elements are considered to be more nearly representative and they also compare more favorably with the values given in Table 2 for the experimental determinations on similar rocks. The flow of heat determined from the rounded 6×10^{-3} of the thermal conductivity from Table 3 would be the same as that previously given for the entire range of observations, namely, 5.7×10^{-7} cal/cm² sec. The three constituent rocks of the area appear to have very little difference in thermal conductivity, and a rounded figure of 6×10^{-7} cal/cm² sec. will closely approximate the flow of heat to the surface. However, as a probable upper limit for the flow of heat through the entire section, the conductivity for the parallel arrangement in granodiorite, 8.4×10^{-3}, may be used with the gradient for the 305–3,715

[4] CROSS, W., IDDINGS, J. P., PIRSSON, L. V., WASHINGTON, H. S. *Quantitative classification of igneous rocks.* Univ. Chicago Press. 1903.

[5] BIRCH, F., and CLARK, H. *Thermal conductivity of rocks and its dependence upon temperatures.* Amer. Journ. Sci. **238**: 529–558, 613–635. 1940.

foot interval thus giving the result 8.1×10^{-7} cal/cm² sec. for the flow of heat.

The figures obtained in these calculations of heat are low compared to the results of Bullard and Krige in South Africa and Benfield[6] in England. In South Africa the surface flow range obtained was $9.5-15.2\times10^{-7}$ cal/cm² sec., mean $11.6\pm0.09\times10^{-7}$ cal/cm² sec.; in England, $6.8-15.3\times10^{-7}$ cal/cm² sec., mean $9.8\pm0.17\times10^{-7}$ cal/cm² sec. If the conductivities of the rocks were measured either in situ or in the laboratory and found to be larger than those used in obtaining the results just given the values of heat flow would of course be larger. Over the potash-bearing area of New Mexico, Richardson and Wells[7] obtained 45 cal/cm² yr. for the flow of heat to the surface through the anhydrite and associated formations, or, converted to the units of this paper, 14.4×10^{-7} cal/cm² sec. The conductivity of the anhydrite and other rock was assumed to be 12.3×10^{-3}.

The somewhat lower heat flow near the surface is probably related to the larger infiltration of water near the surface.[8] In the first 1,000 feet of the Empire mine, about 670 gallons of water a minute are pumped to the surface, and this flow of water could conceivably be the main cuase of the lower temperature gradient and the slightly smaller heat flow in the upper section of the mine.

PALEONTOLOGY.—*Note on a vertebra of* Palaeophis *from the Eocene of Maryland.*[1] S. F. BLAKE, Arlington, Va.

The comparative rarity of fossil remains of snakes makes it desirable to place on record a nearly perfect anterior thoracic vertebra of *Palaeophis* which I collected in 1937 at the well-known Eocene locality at Popes Creek, Charles County, Md. The vertebra was found in the greensand at the very base of the cliff near its upper end, and is therefore to be referred to Zone 17, Woodstock member, Nanjemoy formation (the upper formation of the Pamunkey group). It is the first specimen of this genus to be found in Maryland, and the most nearly complete specimen so far found in this country.

The only Eocene snakes known from the east coast of the United

[6] BULLARD, E. C. *Heat flow in South Africa.* Proc. Roy. Soc. London, A173 (955): 474–502. 1939.
KRIGE, L. J. *Bore-hole temperatures in the Transvaal and Orange Free State. Ibid.:* 450–474.
BENFIELD, A. E. *Terrestrial heat flow in Great Britain. Ibid.:* 428–450.
[7] RICHARDSON, L. T., and WELLS, R. C. *The heat of solution of some potash minerals.* Journ. Washington Acad. Sci. 20: 243–248. 1931.
[8] JOHNSTON, W. D., Jr. *Op. cit.*
[1] Received August 9, 1941.

States, according to Gilmore's monograph,[2] are four species of *Palaeophis*. Three of these, *P. littoralis* Cope, *P. halidanus* Cope, and *P. grandis* (Marsh), are known altogether from only about 6 thoracic vertebrae from the Eocene greensands and marls of New Jersey (Manasquan marl, Vincentown lime, and (probably) Shark River marl). The fourth, *P. virginianus* Lynn, is known from two thoracic vertebrae, one fairly complete, the other very imperfect, collected by Dr. W. G. Lynn on the shore at Belvedere Beach, below the mouth of Potomac Creek, King George County, Va., almost directly across the Potomac River from Popes Creek. These specimens are ascribed to the Aquia formation (the lower formation of the Pamunkey group), which forms the bulk of the deposits at this place. Four additional species of *Palaeophis* are described from the Eocene of England, and one from the Eocene of Belgium. As is the case in most groups of

Fig. 1.—*Palaeophis grandis* (Marsh). Specimen from Popes Creek, Md.: *A*, lateral view; *B*, posterior view; *C*, anterior view. Natural size. Drawn by Sydney Prentice.

fossils known chiefly or entirely from vertebrae, there is doubt whether all the described species are actually distinct.

Gilmore temporarily retains the four described American species of the genus but hints his suspicion that the characters employed in his key are partly or wholly correlated with differences in position in the vertebral column. The vertebrae of the three New Jersey species are distinguished among themselves principally by differences in size, obviously not a good basis for specific distinction when their relative position in the backbone of a 15- or 20-foot snake is unknown, as is also the stage of maturity of the individuals from which they came. *Palaeophis virginianus* stands apart on at least two definite features, its single hypapophysis and its much less extensive neural spine, but these differences also might conceivably be due to differences in position in the vertebral column.

I have been able, in company with Dr. G. G. Simpson, to compare

[2] GILMORE, C. W. *Fossil snakes of North America*. Geol. Soc. Amer. Spec. Pap. 9: 4, 46–56. 1938.

the Maryland vertebra with two vertebrae in the American Museum of Natural History, apparently all that now exist of the three on which *Palaeophis littoralis* Cope was founded. One of these is the comparatively complete specimen figured by Cope, the other too imperfect to be of any value for comparison. The Maryland specimen is about twice the size of the better New Jersey one, but no structural difference of undoubted specific significance is evident. A single vertebra (U.S.N.M. no. 11753) from Vincentown, N. J., referred by Gilmore to *P. littoralis*, is so similar to the Maryland specimen that it is difficult to imagine any specific difference, but it is distinctly smaller.

The single known vertebra of *P. halidanus* Cope, of which I have seen only the illustration, is so fragmentary that satisfactory comparison is impossible, and Gilmore doubts that other specimens can ever be identified with it. The single known vertebra of *P. grandis* (Marsh), of which also I have seen only the figures given by Gilmore, has the hypapophyses represented only by scars and is otherwise more incomplete than the Maryland vertebra, as well as somewhat larger, but on the whole agrees so well with my specimen that it seems permissible to refer the latter to it, at least provisionally. At the same time, I wish to indorse the implicit suggestion in Gilmore's monograph that the three described species from New Jersey really represent only one, although the Virginian species may be distinct. As regards the New Jersey species, at any rate, whatever external or internal distinctive characters the snakes in question might have presented to a contemporary zoologist, the differences observable in their preserved remains are no greater than might be expected in different parts of the vertebral column of a single specimen of such size (around 20 feet) as these animals are supposed to have attained.

I am indebted to C. W. Gilmore for assistance in the preparation of this note, as well as for obtaining the services of Sydney Prentice to make the drawings that illustrate it. The specimen has been placed in the U. S. National Museum (no. 15888). It measures: Div. Vert. Paleont.).

Greatest height	33.8 mm
Width across prezygapophyses	21.5 mm
Length of centrum (edge of glenoid cavity to end of condyle)	20.2 mm
Least width of centrum (near middle)	9.2 mm
Distance from top of zygosphene to lower margin of glenoid cavity	21.2 mm
Height of glenoid cavity	11.0 mm
Width of glenoid cavity	11.8 mm
Height of condyle	10.5 mm
Width of condyle	11.7 mm
Distance between extremities of pre- and postzygapophyses	21.6 mm
Distance between extremities of right and left postzygapophyses	20.1 mm
Height of neural canal in front	5.3 mm
Width of neural canal in front	8.7 mm
Greatest width of zygosphene	11.2 mm

BOTANY.—*Three new species of* Muhlenbergia.[1] CHARLOTTE O. GOODDING. (Communicated by JASON R. SWALLEN.)

During recent study of the specimens at the United States National Herbarium three new annual species of *Muhlenbergia* were found. One species occurs only in Arizona, the second in Arizona, New Mexico, Colorado, Texas, and Mexico, while the third is reported from Arizona and Mexico. Invaluable assistance in the determination of material and in the preparation of the manuscript was given by Jason R. Swallen.

Muhlenbergia appressa C. O. Goodding, sp. nov.

Annua; culmi 10–40 cm longi, erecti vel decumbentes, ramosi, infra nodos scabri vel hispiduli; vaginae striatae, firmae, marginibus membranaceis, internodiis breviores; ligula 2–3 mm longa, hyalina, lacerata; laminae planae vel plicatae, 1–4 cm longae, 1–2 mm latae, scabrae vel pubescentes; paniculae 5–20 cm longae, 0.5–1 cm latae, saepe parte inferiore inclusa, ramis appressis paucifloris; spiculae 4.5–6 mm longae; glumae 1–2 mm longae, obtusae, integrae vel erosae; lemma 4.5–6 mm longum, scabrum, ad basim dense pilosum; arista 10–30 mm longa, scabra; palea acuminata, scabra, ad basim pilosa; granum fusiforme, 2.5 mm longum. Vaginae inferiores reductae, spiculis clandestinis; glumae obsoletae; lemma 3 mm longum, scabrum ad basim pilosum; arista 5 mm longa; granum 2 mm longum, ovatum.

Annual; culms erect to decumbent at the base, 10–40 cm long, much branched below, striate, scabrous to hispidulous below the nodes; sheaths shorter than the internodes, striate, scabrous, firm with membranaceous margins sometimes auricled; ligule thin, lacerate, decurrent, 2–3 mm long; blades flat or folded, scabrous or puberulent, 1–4 cm long, 1–2 mm wide; panicles numerous, as much as 20 cm long, 0.5–1 cm wide, green to purple, very narrow, few-flowered, often included at the base, the branches and pedicels closely appressed; spikelets slender, 4.5–6 mm long, the slender pedicels 0.5–4 mm long; glumes 1–2 mm long or sometimes less, obtuse, entire or erose, thin, pale, contrasting with the bright green scabrous nerve; lemma 4.5–6 mm long, 3-nerved, scabrous above, densely pilose on the callus and margins at the base; awn 10–30 mm long, slender, flexuous, scabrous; palea acuminate, scabrous, short pilose below; anthers 1.5–2 mm long, purplish; grain fusiform, about 2.5 mm long. Cleistogamous spikelets common in the lower reduced sheaths; glumes wanting; lemma about 3 mm long, sparsely scabrous above, pilose on the callus and margins at the base; awn about 5 mm long; grain 2 mm long, ovate.

This species is related to *M. microsperma* (DC.) Kunth, which differs in having a more open panicle with more densely flowered ascending to spreading branches, shorter ligule (1–2 mm long), and shorter lemma (2.5–3.5 mm long or rarely less).

Type.—*Harrison & Kearney 1493* (U. S. National Herbarium no. 1296986), Devils Canyon, Pinal or Gila County, Ariz., March 28, 1926.

Range.—Canyons and slopes of southern Arizona.

Specimens examined.—Devils Canyon, *Peebles, Harrison & Kearney 5085;* mountains above Miami, *L. N. Goodding* in 1941; Camp Creek, Maricopa County, *L. N. Goodding 23–41;* Pima Canyon, *Griffiths & Shear 2628.*

[1] Received July 16, 1941.

Muhlenbergia brevis C. O. Goodding, sp. nov.

Annua; culmi graciles, erecti, 3–20 cm alti, caespitosi, ramosi, infra nodos scabri vel hispiduli; vaginae compressae, carinatae, striatae, firmae, marginibus membranaceis, internodiis longiores; ligula 1–3 mm longa, hyalina, lacerata; laminae planae vel involutae, 0.5–4 cm longae, 1–2 mm latae, supra scabrae vel pubescentes, infra scabrae; paniculae 1–12 cm longae, ca. 0.5 cm latae, saepe parte inferiore inclusa, ramis erectis usque ad 1 cm longis; spiculae 4–5 mm longae; glumae scabrae, quam flosculus breviores; gluma prima 1–3 mm longa, 2-nervia, minute vel profunde bifida; gluma secunda 1.5–4 mm longa, 1-nervia, acuminata vel setacea; lemma 4–5 mm longum, 3–5-nervium, scabrum, ad basim sparse pubescens; arista 10–20 mm longa, scabra; palea 4–5 mm longa, acuminata, scabra.

Annual; culms erect, 3–20 cm tall, slender, tufted, much branched below, scabrous to hispidulous below the nodes; sheaths compressed, keeled, striate, firm with membranaceous margins, usually longer than the internodes, the lower ones often spreading; ligule 1–3 mm (usually about 2 mm) long, thin, lacerate, often auriculate; blades flat to involute, 0.5–4 cm long (mostly 2–3 cm), 1–2 mm wide, scabrous or puberulent above, scabrous below, with white cartilaginous midrib and margins; panicles 1–12 cm long, less than 0.5 cm wide, often included at the base, rather densely flowered, pale green tinged with purple, the branches erect, as much as 1 cm long; spikelets slender, 4–5 mm long; glumes scabrous, variable, shorter than the floret; first glume 1–3 mm long, 2-nerved, minutely to deeply bifid, the slender teeth sometimes widely spreading; second glume 1.5–4 mm long (usually 2–3 mm), 1-nerved, narrow, acuminate to setaceous; lemma lanceolate, 4–5 mm long, prominently 3-nerved (rarely 5-nerved), scabrous especially on the nerves, sparsely to rather densely appressed pubescent between the nerves toward the base; awn 10–20 mm (rarely less) long, slightly flexuous, scabrous; palea 4–5 mm long, acuminate, scabrous; grain fusiform, 2.5 mm long.

This species is closely related to *M. depauperata* Scribn., which differs in having a shorter lemma (3–3.5 mm long) with a shorter awn (5–10 mm long or less) and glumes about as long as the floret.

Type.—*Metcalfe 671* (U. S. National Herbarium no. 495644), Mogollon Mountains, on Mogollon Creek, Socorro County, N. Mex., September 8, 1903.

Range.—Open ground at higher elevations, Colorado and Texas to Arizona, south to the Federal District, Mexico.

Specimens examined.—ARIZONA: Bowie, *Jones* in 1884. COLORADO: Rio Grande Forest, Conejos County, *Kutzleb* (U. S. Forest Service *66111*). NEW MEXICO: Black Range, *L. N. Goodding M-271*, *L. N. & C. Goodding M-377*, *Metcalfe 1362*; Datil National Forest, *Talbot 47*; Mimbres Mountains, *L. N. & C. Goodding M-380* no locality given, *Wright 2017*. TEXAS: Mount Livermore, *Hinckley 523*. CHIHUAHUA: Sanchez, *Hitchcock 7664*. DURANGO: Sandia Station, *Pringle 13634*. SAN LUIS POTOSÍ: San Luis Potosí, *Schaffner* in 1877 and 1879. FEDERAL DISTRICT: Churubusco, *Orcutt 4311*.

Muhlenbergia pectinata C. O. Goodding, sp. nov.

Annua; culmi 10–25 cm longi, erecti vel decumbentes, ad nodos inferiores radicantes, ramosi, graciles, glabri vel infra nodos scabri; vaginae internodiis longiores, striatae, in ore plusminusve pilosae, saepe marginibus ciliatis; ligula hyalina, erosa vel ciliata, ca. 0.5 mm longa; laminae planae

vel involutae, pubescentes vel pilosae, 1–6 cm longae, 1–2 mm latae; paniculae 2–12 cm longae, ca. 0.5 cm latae, exsertae vel parte inferiore inclusa, ramis 0.5–4 cm longis, appressis, ad basim floriferis; spiculae 3.5–4.5 mm longae; glumae 1.5–3 mm longae, abrupte acutae vel acuminatae, aristatae; lemma 3–5 nervium, nervis lateralibus scabris vel ciliatis, callo pubescente; arista 10–30 mm longa, gracilis, flexuosa; palea acuminata lemma aequans.

Annual; culms 10–25 cm long, leafy, erect to decumbent, sometimes rooting at the lower nodes, slender to filiform, freely branching, glabrous to scabrous below the nodes, angular, usually square in cross section; sheaths commonly longer than the internodes, striate, more or less pilose at the throat, the margins often ciliate; ligule thin, erose to ciliate, about 0.5 mm long; blades flat to involute, divergent, pubescent to sparsely pilose, 1–6 cm long, 1–2 mm wide; panicles numerous, very narrow, exserted or more often included at the base, 2–12 cm. long, about 0.5 cm wide, the branches 0.5–4 cm long, appressed, floriferous from the base or nearly so; spikelets narrow, terete, 3.5–4.5 mm long; glumes equal or unequal, 1.5–2 mm or sometimes 3 mm long, prominently 1-nerved, scabrous on the nerve, abruptly acute or acuminate, commonly aristate, the awn usually about one-half the entire length; lemma prominently 3-nerved, with usually 2 intermediate nerves, scabrous to prominently ciliate on the lateral nerves, the callus appressed pubescent; awn 10–30 mm long, slender, flexuous; palea long-acuminate, as long as or slightly longer than the lemma.

This species is related to *M. ciliata* (H.B.K.) Kunth, which differs in having spreading panicle branches and shorter lemmas (2–2.5 mm long), shorter awns (3–12 mm long). It is also closely allied to *M. tenella* (H.B.K.) Trin., which differs in having smaller spikelets (2–2.5 mm long).

Type.—*Pringle 1745* (U. S. National Herbarium no. 995478), moist ledges of the barranca near Guadalajara, Jalisco, Mexico, November 1, 1888.

Range.—Moist rocky hillsides of southern Arizona, south to Jalisco, Mexico.

Specimens examined.—ARIZONA: Mule Mountains, Cochise County, *L. N. Goodding M-348, L. N. & C. Goodding M-406;* Sycamore Canyon, Santa Cruz County, *L. N. Goodding M-318, M-375, A-9386.* SONORA: Canyon de Huépari, north of Aribabi, *Harvey 1742.* CHIHUAHUA: Batopilas, *Palmer* in 1885. DURANGO: Vicinity of Durango, *Palmer 719* in 1896. JALISCO: Chapala, *Holway 3479;* Guadalajara, *Palmer 404* and *481* in 1886; Tequila, *Pringle 5395;* Zapotlan, *Hitchcock 7257.*

PALEOBOTANY.—Pinus *and* Quercus *in the Chesapeake Miocene.*[1]

EDWARD W. BERRY, Johns Hopkins University.

In 1936 I described a pine cone from the Calvert Cliffs Miocene under the name of *Pinus collinsi*,[2] naming it after the collector. Obviously the specimen furnished few features for a specific diagnosis, or for useful comparisons with other described species, either recent or fossil. I remarked on the apparent scarcity of land plants in these shallow-water marine sediments. In the past few years detailed examination of these strata by Dr. R. E. Lee Collins and by Dr. Charles T.

[1] Received June 30, 1940.

[2] Torreya 36: 125, fig. 2. 1936.

Berry has demonstrated that remains of land plants, although uncommon as might be expected, are not nearly so rare as had been assumed, and incidentally, the same remark might be made of land animals. It is the purpose of the present note to comment on some additional occurrences.

Pinus collinsi Berry

These cones are in the same poor state of preservation and with the same lack of specific characters as the type. Sometimes they are fairly complete. At others they are badly broken up, or not much more than the macerated cone axis is preserved. Superficially they all appear to belong to the single species, but this is incapable of proof.

To date they have been collected from the following localities and horizons: 1.7 miles south of Plumpoint, Zone 11 of Calvert formation (type); 1½ miles south of Plumpoint, Zone 10 of Calvert formation; ¼ and ½ mile north of Governors Run, Zone 14 of the Calvert formation; 2 miles south of Cove Point, Calvert County, St. Marys formation. The foregoing are all in Maryland. In addition, similar cones have been found near the south end of Stratford Cliffs (Nomini), Westmoreland County, Va., in the Calvert formation.

At the locality 1½ miles south of Plumpoint, the cones are associated with driftwood of *Pinus* and fragments of dicotyledonous leaves. Figs. 1 and 2 show the usual condition of these cones. The lignite to which they have been altered is structureless, and if not treated before drying with gum arabic, paraffin, or duco they disintegrate very rapidly.

Quercus sp.

Several acorns of some species of oak were collected in 1937 at Stratford Cliffs, 1 mile below the mouth of Popes Creek, Westmoreland County, Va., by Charles T. Berry. They are about 1.5 cm in length by 1 cm in diameter and afford no diagnostic features.

The following species of oaks, based upon leaves, were described in 1916 from near shore phases of the Calvert formation at Richmond, Va., and from two localities in the District of Columbia near Washington[3]: *Quercus calvertonensis*, *Quercus chapmanifolia*, and *Quercus lehmani*. The first was compared with the modern *Quercus alba*, the second with *Quercus chapmani*, and the third with *Quercus emoryi*. If any conclusion can be drawn from these most similar living relatives, which is perhaps doubtful, the Miocene *Quercus chapmanifolia* and *Quercus lehmani* should have had acorns smaller than the present fossil. It would seem that *Quercus calvertonensis*, though a smaller-leafed form than the existing *Quercus alba*, was the only one of the Miocene species based on leaves with which the fossil acorn should be correlated, although this is, of course, problematical.

The known Miocene flora of the middle Atlantic slope is one of cypress

[3] BERRY, EDWARD W., U. S. Geol. Surv. Prof. Paper 98: 61–73, pls. 11, 12. 1916.

swamps, sand dunes, and beach ridges. Whether these ecological groups are merely the normal reflection of the coastal zone in shallow marine sediments or whether they are of wider climatic significance can not be determined from present information. That there was less runoff from the land, or at least less terriginous material in the water, thus permitting the accumulation of the diatomaceous beds that are so prominent a feature of the earlier Miocene sediments in this region, is certainly well established.

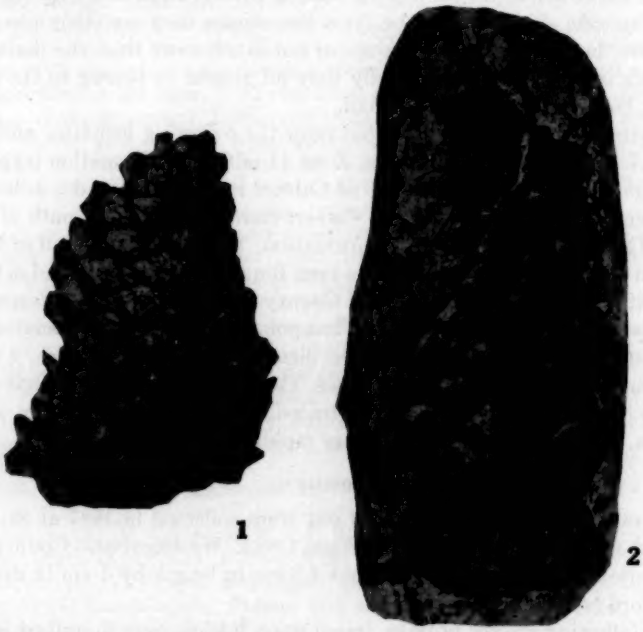

Fig. 1.—*Pinus collinsi* Berry, from 1½ miles south of Plumpoint, Md.
Fig. 2.—*P. collinsi* from south end of Stratford Cliffs, Va.

The known flora appears, as judged by present-day conditions, to be about normal to the latitude. There is considerable evidence from the little that is known about the Tertiary floras of the eastern United States that the Miocene climate was somewhat cooler than that of the Eocene, and there is overwhelming evidence in the fossil floras of other parts of the world, notably in the Mississippi embayment, northern Europe, and the Arctic, that this was a world-wide condition. There is also considerable evidence that the contemporaneous marine fauna of the Calvert is a cooler-water fauna than those of the earlier Tertiary and also, although to a lesser degree, than those of the later Tertiary.

ZOOLOGY.—*New species and distribution records of diaptomid copepods from the Marsh collection in the United States National Museum.*[1] MILDRED STRATTON WILSON. (Communicated by WALDO L. SCHMITT.)

This paper is based on the material concerning the genus *Diaptomus* that accumulated in the collection of Dr. C. Dwight Marsh following the publication of his paper on the distribution of the genus in 1929. His studies on other fresh-water calanoids were entirely included in the posthumous paper published in 1933. There were found in the collection, in addition to new distribution records, slides of two undescribed species. Of these, the one from a collection made in Guatemala is represented by several slides. The name *D. amatitlanensis*, given by Dr. Marsh in his notes, is retained. The other species, from a collection made in New Jersey, is named *D. lighti* for Prof. S. F. Light, of the University of California. *D. lighti* is represented by a unique male specimen, unfortunately incomplete as regards the right antennule. Since the specimen shows no indication of abnormality and is distinctly different from other related diaptomids, it is being designated a new species.

There was also found a mounted specimen of *D. augustaensis* Turner, 1910, hitherto known only from the original collection. Since Turner's description was not complete, especially as regards the left fifth leg and the modified right antennule of the male, it is redescribed on the basis of the newly found specimen.

DISTRIBUTION RECORDS

Dr. Marsh included most of the known information about the distribution of *Diaptomus* in his paper on the distribution of the genus (1929). Later (1931) he published a paper on collections made in El Salvador, which reported finding there *D. marshi* and *D. siciloides*. Wright had also found *D. siciloides* in Lake Erie, and his material is a part of the Marsh collection in the National Museum. Marsh mentioned (1931) that Bajkov also found *D. siciloides* in Lake Winnipegosis, Manitoba. Bajkov (1929) added further distribution records for Manitoban lakes, as follows: *D. ashlandi*, *D. leptopus*, *D. shoshone*, *D. sicilis*, and *D. tenuicaudatus*. Of these, a mounted specimen of *D. ashlandi* is in the Marsh collection.

Unpublished records of collections made by or presented to Dr.

[1] Received July 11, 1941.

Marsh follow. The notes concerning these collections are very brief, and complete information is often lacking.

D. ashlandi Marsh: Klamath Lake, Klamath Falls, Oreg., collected by C. D. Marsh, August 26, 1929.

D. augustaensis Turner: Chapel Hill, N. C., collected by R. E. Coker, May 1931.

D. bacillifer Kölbel: Tundra pond on east side of Lake Harbour, southern coast of Baffin Land, collected by F. Johansen, August 23, 1927.

D. clavipes Schacht: Ada, Pontotoc County, southern Oklahoma, collected by J. G. Mackin, contributed by S. Wright.

D. eiseni Lilljeborg: Tundra ponds at Port Burwell and Wakeham Bay, Hudson Strait, collected by F. Johansen, 1927.

D. minutus Lilljeborg: White Lake, N. C., collected by R. E. Coker, first record of occurrence south of Indiana (Marsh 1929); Newton, Mass., collected by C. B. Wilson. Wilson (1932) has reported *D. minutus* from the Woods Hole region.

D. oregonensis Lilljeborg: Flathead Lake, Mont.

D. sanguineus Forbes; Ada, Pontotoc County, southern Oklahoma, collected by J. G. Mackin, contributed by S. Wright.

D. sicilis Forbes: Flathead Lake, Mont., collected by R. T. Young, August 10, 1929; Gabas road (?) near Midland, Oreg., collected by C. D. Marsh, August 27, 1929. The most western location reported for *D. silicis* has been Yellowstone Park (Marsh 1929).

SYSTEMATIC DISCUSSION

Diaptomus amatitlanensis, n. sp. Fig. 1, *a–d*

Specimens examined.—Thirty-six mounted specimens, 17 female, 19 male, Marsh slides 5402–5405 and 5409–5419. Collected by Chancey Juday in Lake Amatitlan, Guatemala, February 5, 1910. Male holotype, U. S. N. M. no. 79366, Marsh collection, slide 5409.

Description.—Metasome convex in dorsal profile, tapering slightly posteriorly. Urosome relatively short, furcal setae short; furca ciliated on both inner and outer margins. Antennules reaching to end of furca.

Female: Length about 1.4–1.5 mm, exclusive of furcal setae. Last segment of metasome bearing a blunt dorsal tooth, variable in size; posterolateral projections inconspicuous, rounded, bearing two spines; spine of dorsal side minute, sharply pointed, that of lateral tip stout, somewhat curved. Spines of genital segment of urosome stout and long; second segment shortened, right side produced into prominent spine-like caudal process. *Fifth legs:* Relatively slender, with long, stout basal spines. Third segment of exopodite distinct, its spine twice the length of seta. Spine of second segment short; claw almost as long as inner margin of first segment, nearly straight; outer margin of claw bearing two slender teeth or none; inner margin with ten to eighteen stout teeth on anterior surface. Endopodite half the length of inner margin of first segment of exopodite, bearing two short setae, inserted subapically and extending slightly below the tip, lateral seta one-third longer than median; tip truncate, with a narrow asymmetrically placed groove bordered by a line of slender hairs.

Male: Length about 1.25–1.4 mm, exclusive of furcal setae. Left antennule with usual setal formula. Right antennule markedly swollen, major spines on segments 10, 11, and 13; those on 10 and 11 slender, slightly curved, length less than width of segments; spine on segment 11 about one-

third longer than that on segment 10. Spine on segment 13 large, almost twice as long as width of segment, broad at base, tapering, obliquely directed. Segment 14 with conspicuous, obliquely directed spinous process arising at proximal angle, and almost as long as spine on segment 13. Small, distally directed spinous processes at mid-margin of segments 15 and 16. Processes of segments 14, 15, 16 and depressed process of segment 17, accompanied by modified setae, stiff, slender and blunt-ended. Process on antepenultimate segment tapering, slightly outcurved, length less than that of penultimate segment. *Fifth legs:* Relatively narrow, left leg reaching to slightly beyond distal end of first segment of right exopodite. Basal spines long and stout. *Right leg:* Basal segment about as long as wide, margins rounded. Second basal segment much longer than wide, lateral hair at distal fourth; a somewhat diversified process ending in a rounded lobe projects transversely on the distal posterior face. First segment of exopodite short, wider than long, outer margin longer than inner, terminating in distally directed lobe; running across the posterior face of the segment from near outer to near inner margin is a triangularly elongate ridge with its distal extremity narrowed; a small rounded lamella projects from the distal border of the segment. Second segment broad, length less than twice width; midway of the segment, beginning at the medial margin, is a straight, obliquely directed ridge; lateral spine near distal end, relatively slender, length less than width of segment, distal half curved. Claw about as long as rest of leg excluding first basal segment, strongly curved in distal half, inner margin finely denticulate. Endopodite short and wide, reaching slightly beyond first segment of exopodite, bearing laterally on inner margin (rarely on outer) a slender, distally-directed seta; tip truncate, set with circular line of slender hairs. *Left leg:* Basal segments subequal, longer than wide; lateral hair slightly in front of distal third of second segment. Exopodite less than one-half length of basipodite; first segment longer than second, pad large, bearing short slender hairs. Processes of apical segment very small, the distal broad, blunt, not set off sharply; the lateral spine-like, slender, tapering and curved; proximal pad set with long slender hairs; distal pad extending nearly to tip of distal process, set with coarse recumbent hairs. Endopodite narrow, reaching slightly beyond first segment of exopodite; bearing laterally a slender seta; tip with an asymmetrically curved line of slender hairs.

Taxonomic position.—Diaptomus amatillanensis belongs to the subgenus *Mastigodiaptomus* Light, 1940, and resembles the other included species, *D. albuquerquensis* Herrick and *D. purpureus* Marsh in all the major subgeneric characters. It is interesting that *D. albuquerquensis* appeared in the same collection from which the type species of *D. amatillanensis* has been described (Juday, 1915).

D. amatillanensis is seemingly most closely related to *D. purpureus* in that the lateral spine of the right fifth leg of the male is short, while in *D. albuquerquensis* it is comparatively much longer. The setae of the left leg of the female are intermediate in length between those of *D. albuquerquensis* and *D. purpureus.* It differs distinctly from both other species in the absence of a hyaline lamella on the medial border of the second basal segment of the male right leg and in the broad, bulging second segment of the exopodite of the right leg of the male.

Diaptomus lighti, n. sp. Fig. 1, *h–j*

Specimens examined.—Unique male holotype, U.S.N.M. no. 79368, Marsh

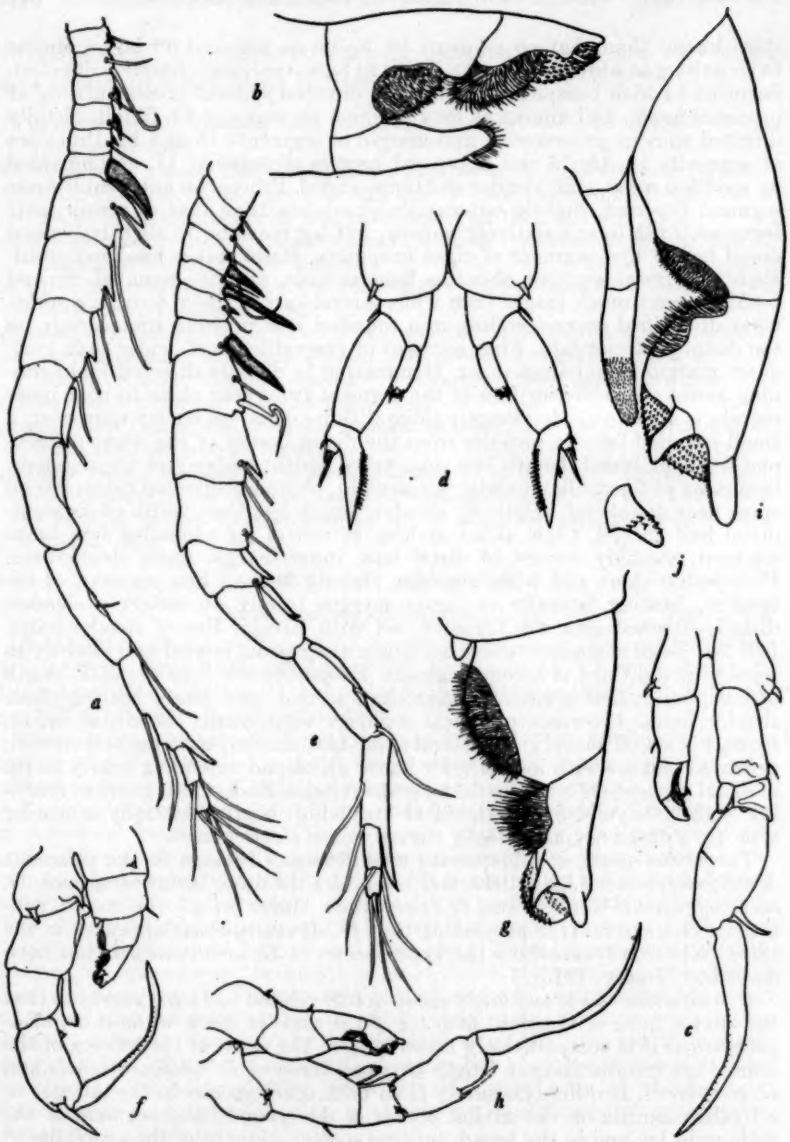

Fig. 1.—*a-d, Diaptomus amatitlanensis*, new species: *a*, Right antennule (male); *b*, left fifth leg (male), anterior view; *c*, fifth pair of legs (male), posterior view; *d*, fifth pair of legs (female). *e-g, Diaptomus augustaensis: e*, Right antennule (male); *f*, fifth pair of legs (male), anterior view; *g*, left fifth leg (male), anterior view. *h-j, Diaptomus lighti*, new species: *h*, Fifth pair of legs (male), anterior view; *i*, left fifth leg (male), anterior view; *j*, proximal process of second segment of exopodite of left fifth leg (male), inside.

collection, slide 5355. Collected by Dr. C. D. Marsh in Big Timber Creek, Gloucester, N. J., September 19, 1931.

Description.—Female unknown.

Male: Length 1.75 mm, exclusive of furcal setae. Urosome relatively long, segments subequal in length, distal two abruptly narrowed. Antennules not reaching to end of furca; left with usual setal formula, three on segment 2, two each on segments 9, 11, and 22–24, five on segment 25, one on all others. Right antennule missing beyond third segment, showing evidence of having been broken prior to collection. *Fifth legs:* Elongated; left leg reaching to slightly beyond distal end of first segment of right exopodite. Spines of first basal segments short and slender. *Right leg:* Basal segment short and broad, rounded on outer margin; inner margin with broad, distally directed, spine-like lamella on distal posterior face. Second segment twice as long as broad; inner margin rounded; outer margin incurved proximally; hair short, at distal third of segment. First segment of exopodite subquadrate, straight-sided, distal lateral corner ending in a rounded, distally directed lobe; next to this lobe on the anterior face and overlying the next segment, is a longer clawlike lamella, curving outward; at inner distal angle on the posterior face is a small rounded lamella; running along the entire inner margin is a hyaline lamella with widened, tonguelike free end, projecting beyond the distal angle of the segment. Second segment about twice as long as broad, outer margin convex; lateral spine slightly in front of distal third of segment, length more than half diameter of segment, somewhat curved; in specimen described, the distal half of spine is bent in a right angle to the proximal so extent of curvature cannot be determined. Claw longer than the rest of exopodite. Endopodite short, not reaching distal end of first segment of exopodite, acuminate, distal surface minutely setose. *Left leg:* First basal segment subquadrate; inner face of second segment strongly convex, longer than outer, exceeding width of segment; outer margin concave, hair short, near distal end. Exopodite narrowed; first segment longer than second, outer face longer than inner; pad set with short, fine hairs. Second segment with inner face distinctly rounded; proximal pad with long slender hairs, distal pad set with short spinelets; processes short, subequal, digitiform; terminal distally directed, armed with inner marginal row of short setae; lateral process directed somewhat obliquely, armed on distal half of posterior inner face with rows of spinelets directed outward so that the tips of the outer spinelets project beyond the proximal margin of the process. Endopodite long, extending beyond middle of second segment of exopodite, 2-segmented, distal end blunt, dentate.

Taxonomic position.—*D. lighti* clearly belongs to the subgenus *Leptodiaptomus* Light, 1938. The characters of the left exopodite of the male fifth leg fit the diagnosis given for that group. It differs from any other member of the group in the shape, size and attachment of the hyaline lamella on the inner margin of the first segment of the right exopodite. This lamella, undoubtedly homologous with that in a similar position in many of the other species of the group, most closely resembles that of *D. signicauda.* It differs in being broader, less rounded distally, and in being attached only along the margin of the segment. The species is not only considerably larger than *D. signicauda,* but is large for the group as a whole. *D. lighti* is uniquely distinguished by the distinct claw-like lamella on the anterior face of the first segment of the right exopodite.

Diaptomus augustaensis Turner, 1910 Fig. 1, *e–g*

Specimens examined.—Unique male specimen, Marsh slide 5317. Collected by R. E. Coker at Chapel Hill, N. C., May, 1931.

Description.—Male: Length approximately 2.5 mm (measurements based on dissected specimen). Left antennule with usual setal formula. Segments 14–16 of right antennule markedly swollen, major spines on segments 10, 11, and 13 conspicuous, straight, longer than width of segments; that on 11 longest, almost twice length of that on segment 10; spine on segment 13 widest, almost as long as that on segment 11. Large, distally directed spinous process on distal third of segment 15. Process of antepenultimate segment tapering, longer than penultimate segment. *Fifth legs:* Basal spines short and stout. *Right leg:* First basal segment about as long as broad, margins rounded; large hyaline lamella on distal half of anterior inner surface, broad at base, terminating in curved distally directed process. This process partially overlies a hyaline lobe on the proximal inner margin of the second segment. Inner margin of second segment longer than outer, lobe extended as narrow hyaline border for two-thirds of its length. First segment of exopodite narrowed distally, outer margin longer than inner. Length of second segment more than twice width, outer margin concave; prominent spine at proximal fourth of inner margin. Lateral spine close to distal end, stout, slightly longer than width of segment. Claw longer than exopodite, strongly curved, denticulate on inner margin. Endopodite slender, one-fourth longer than first segment, inner margin setose in distal fourth, terminating in short rounded process. *Left leg:* Basal segments subequal in length, wider than long. Lateral hair at distal angle of second segment. First segment of exopodite almost as long as wide, pad narrow with short, slender hairs; apical segment longer than wide, terminal process short, digitiform; lateral process a flat, broad, curving spine, armed on distal half of upper margin with short, stiff setae; pads large, proximal set with long slender hairs, distal with rows of conspicuous, heavy spinelets. Endopodite rudimentary.

Taxonomic position.—D. augustaensis clearly belongs to the subgenus *Hesperodiaptomus* Light, 1938, as indicated by the flat, curving, spinelike proximal process of the terminal segment of the left fifth leg of the male and the distal location of the lateral spine of the second segment of the exopodite of the right leg; the presence of a third segment in the exopodite of the fifth leg of the female (Turner, 1910); and the long spinous process on the antepenultimate segment of the right antennule of the male. It differs markedly from the other species of the subgenus in numerous particulars, notably the relatively large blunt spine on the inner face of the second segment of the exopodite of the right fifth leg of the male, the unusual hyaline membranes of the first and second basal segments of the same leg, and in the rudimentary endopodite. This endopodite may be variable in character. A first glance at Turner's drawing in the description of the type makes it appear that the endopodite is longer than noted in the specimen herein described, but if the drawing is reconstructed so that the endopodite bears its proper relationship to the second basal segment, instead of arising as it seems to as a part of the first basal segment, it would appear to be also very much reduced. Turner's description of the species refers to it as a "small, slender species," but the specimen herein described is comparatively large, as are many other species of the subgenus.

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

369TH MEETING OF THE BOARD OF MANAGERS

The 369th meeting of the Board of Managers was held in the Library of the Cosmos Club on Friday, October 3, 1941. President CLARK called the meeting to order at 8:05 P.M., with 14 persons present, as follows: A. H. CLARK, F. D. ROSSINI, H. S. RAPPLEYE, J. H. KEMPTON, F. C. KRACEK, J. E. GRAF, F. H. H. ROBERTS, JR., F. G. BRICKWEDDE, H. B. COLLINS, JR., F. M. SETZLER, H. L. CURTIS, L. W. PARR, C. L. GARNER, and, by invitation, R. J. SEEGER.

The minutes of the 368th meeting were read and approved.

The President announced the following appointments: R. J. SEEGER, to be the Academy's delegate to the 175th anniversary celebration of Rutgers University, at New Brunswick, N. J., on October 9 to 11, 1941; C. L. GARNER (chairman), R. E. GIBSON, L. V. JUDSON, W. C. LOWDERMILK, P. A. SMITH, and CHARLES THOM, to constitute the Committee on Meetings, until May, 1942.

The Board considered and elected to membership one resident person.

The Committee to Publish the Directory for 1941, H. S. RAPPLEYE and F. D. ROSSINI, presented its report as follows:

In accordance with the action taken by the Board of Managers at its meeting on March 14, 1941, the 1941 Directory of the Academy and its Affiliated Societies was produced by the photolithographic process, in the usual 6 by 9 inch size with a red cover, and with a new form of contents. In the lists of members of the affiliated societies, the names of those persons who are also members of the Academy are marked with an asterisk.

In the production of the 1941 Directory, the master pages of the copy in its new form were typed by a private individual under special contract, in order to provide for close contact with the work and to make possible changes in copy at a minimum of cost. The job of planographing and printing

and binding was let to the A. L. Sauls Planograph Co., 909 E. Street, NW., Washington, D. C., the lowest of four bidders. The Directory was distributed on September 1, 1941.

There occurred in the 1941 Directory two important errors which should be guarded against in future editions. One of these was an error of omission by the Committee and the other was an error of commission in the binding of the book, as follows: (1) Page numbers were inadvertently omitted from the contents page; (2) a number of the pages in the book are misaligned. To compensate for the latter error, the A. L. Sauls Co. made an allowance of $12 in the cost of producing the Directory.

The cost of producing 1,000 copies of the 1941 Directory for the Academy was as follows:

Solicitation and preparation of the copy for the 19 affiliated societies		$ 16.29
Preparing the master copy by typing		78.87
Proof-reading the master copy		16.65
Planographing, printing, and binding	$192.40	
Less allowance for misalignments of pages	12.00	180.40
Total		292.21

By arrangement with the printer, additional copies of the Directory, over and above the 1,000 provided for the Academy, were prepared at a cost of $9.36 per hundred, for distribution on prepublication order to the affiliated societies at $10.00 per hundred, as follows:

Philosophical Society	275 copies	$27.50
Botanical Society	100 "	10.00
Institute of Radio Engineers	100 "	10.00
Anthropological Society	50 "	5.00
Total	525 "	52.50
Cost to the Academy		49.14
Profit to the Academy on these 525 copies		3.36

The net cost to the Academy of the 1941 Directory is therefore $288.85, and, since the Committee was allotted $350 for the 1941 Directory, there will remain, when the accounts are settled, an unexpended balance of $61.15.

On the basis of its experience with the 1941 Directory, the Committee wishes to recommend two changes for the next edition of the Directory:

(1) The booklet should be flat-stitched instead of saddle-stitched, even though the cost will be somewhat greater. There are too many pages in the Directory to make saddle-stitching satisfactory.

(2) The master pages should be prepared with the new, large character, bold-face type now available on special typewriters for photolithographic work, instead of with the type on ordinary typewriters. A sample of how this special bold-face type would appear when reduced to the size used in the 1941 Directory is attached in the form of a copy of page 41 of this Directory. The corresponding page from the 1941 Directory is attached for comparison.

The Committee also wishes to recommend that the Board of Managers authorize the President to appoint a Committee to consider the following questions with regard to future editions of the Directory:

(1) Should the Directory be published annually instead of biennially?

(2) Should the affiliated societies be asked to contribute a nominal sum to the cost of the Directory? For example, for those societies giving lists of members, the assessment might be 1½ or 2 cents per member, or perhaps $2 for each printed beyond the first.

(3) Should the duties of the Board of Editors be redefined to include all publications of the Academy? This would bring the preparation of the Directory under their jurisdiction.

The Board accepted this report and authorized the appointment of a Committee to Consider the Policy for Future Editions of the Directory.

The Secretary presented the following information concerning the membership: Deaths, 5; acceptances to membership, 7; qualified for membership, 9; retirements, 2. The status of the membership as of October 2, 1941, is as follows:

	Regular	*Retired*	*Honorary*	*Patrons*	*Total*
Resident	433	33	3	0	469
Nonresident	131	16	13	3	163
Total	564	49	16	3	632

The Treasurer reported that, in accordance with instructions from the Executive Committee, the funds on deposit in a savings account with the American Security and Trust Co. were placed on deposit in two accounts in federally-insured savings and loan associations, as follows: $4,000 in the First Savings and Loan Association, currently paying 3 percent interest, and $4,500 in the Northwestern Savings and Loan Association, currently paying 3½ percent interest. The following changes in investments were reported: The principal amount, $4,000, of real-estate notes of the Ell and Kay Investment Co., on apartment-house property at 5420 Connecticut Avenue, will be paid to the Academy on October 15, 1941; the Butler real-estate notes on garage property at 1707 L Street, NW., having a face value of $2,000, will, within 30 days of September 19, 1941, bring $1,200 (less commission) to the Academy, as a result of the trustees for the note holders being forced to dispose of the property at a loss; the Yetta Korman real-estate notes, on apartment-house property at 7302–7310 Georgia Avenue, NW., having a face value of $1,000, are being extended 3 years to October 5, 1944, with interest at 4½ percent.

The Secretary read to the Board certain proposed amendments to the bylaws, whose purpose is to (1) include in Article II, which lists the officers of the Academy and indicates the manner of their selection, the manner of selecting the Custodian and Subscription Manager of Publications, and (2) include in Article III, which gives the duties of these officers, a statement of the duties of the Archivist and of the Board of Editors. At the present time, the Custodian and Subscription Manager of Publications has his duties described in Article III, but there is no statement in Article II as to the manner of his selection. Contrariwise, the Archivist does not have his duties described in Article III, but there is in Article II a statement as to the manner of his selection. The duties of the Board of Editors are at present described in the Standing Rules of the Board. The Board instructed the Secretary to distribute copies of these amendments to each member of the Board, for appropriate action at the next meeting.

The meeting adjourned at 9:25 P.M.

306TH MEETING OF THE ACADEMY

The 306th meeting of the Academy was held in the Assembly Hall of the Cosmos Club at 8:15 P.M. on Thursday, October 16, 1941, with President CLARK presiding. FRANCIS W. REICHELDERFER, Chief of the U. S. Weather Bureau, delivered an address entitled *Some famous weather maps*. In his talk, Commander REICHELDERFER discussed the first weather maps, traced the evolution of the modern weather map, and indicated the work involved in its preparation, and showed, by map, the weather conditions holding at the times of a number of noteworthy storms in this country. The importance of air-mass analysis in the work of the Weather Bureau was briefly described.

There were about 145 persons present. The meeting adjourned at 9:30 P.M. for a social hour.

370TH MEETING OF THE BOARD OF MANAGERS

The 370th meeting of the Board of Managers was held in the Library of the Cosmos Club on Friday, November 7, 1941. President CLARK called the meeting to order at 8:03 P.M., with 20 persons present, as follows: A. H. CLARK, F. D. ROSSINI, N. R. SMITH, W. W. DIEHL, J. H. KEMPTON, J. H. HIBBEN, F. C. KRACEK, J. E. GRAF, F. H. H. ROBERTS, JR., F. G. BRICKWEDDE, H. B. COLLINS, JR., F. M. SETZLER, R. M. HANN, A. WETMORE, H. L. CURTIS, J. R. CHRISTIE, L. W. PARR, C. L. GARNER, and, by invitation, R. J. SEEGER and G. A. COOPER.

The minutes of the 369th meeting were read and approved.

President CLARK announced the following appointments: Committee to Consider the Policy for Future Editions of the Directory, H. L. CURTIS (chairman), F. C. KRACEK, L. W. PARR, and F. H. H. ROBERTS, JR.

Chairman KRACEK of the Committee on Membership presented nominations for membership for 7 persons, 6 resident and 1 nonresident.

The Committee on Nominations, H. E. MCCOMB, chairman, reported that the following nominations for officers for 1942 had been made: For president, HARVEY L. CURTIS; for Secretary, FREDERICK D. ROSSINI; for Treasurer, HOWARD S. RAPPLEYE; for Manager, to January, 1945, with two to be elected, SIDNEY F. BLAKE, ROBERT F. GRIGGS, FRANK C. KRACEK, and BEN H. NICOLET.

The Secretary reported the following data relating to the membership: Deaths, 1; acceptances to membership, 1; resignations, 2. The status of the membership as of November 6, 1941, is as follows:

	Regular	*Retired*	*Honorary*	*Patrons*	*Total*
Resident	433	33	3	0	469
Nonresident	128	18	13	3	162
Total	561	51	16	3	631

The amendments to the bylaws previously circulated to the Board were approved for submission to vote of the membership. The proposed amendments are as follows:

Article II

(1) In the second sentence of Section 1, interchange "4" and "5," and after "Manager of Publications" insert "(see Section 6)."

(2) Interchange the numbers and position of Sections 4 and 5.

(3) Add the following new Section: "Section 6.—The Custodian and Subscription Manager of Publications shall be appointed by the President for a period of three years."

Article III

(1) Change the number of the present Section 4 to Section 6.

(2) As new Section 4, insert the following: "Section 4.—The Archivist shall maintain in good order all of the permanent records of the Academy. These shall include the important records that have passed out of current use from the offices of the Secretary, Treasurer, etc., and such other documents and material as the Board of Managers may direct."

(3) As new Section 5 insert what is now Rule 7 of the Standing Rules of the Board of Managers: "Section 5.—The Board of Editors shall have charge of the Journal of the Academy. The Senior Editor shall sign all contracts on behalf of the Journal. Associate Editors shall be appointed by the President for a term of three years."

The meeting adjourned at 8:50 P.M.

307TH MEETING OF THE ACADEMY

The 307th meeting of the Academy was held in the Assembly Hall of the Cosmos Club at 8:15 P.M. on Thursday, November 27, 1941, with President CLARK presiding. MATTHEW W. STIRLING, Chief of the Bureau of American Ethnology of the Smithsonian Institution, assisted by Mrs. STIRLING delivered an illustrated address entitled *Treasure trove of Mexican archeology*. The lecture described pictorially the National Geographic Society–Smithsonian Institution Archaeological Expedition to southern Mexico during the winter of 1940–41, which conducted excavations at the site of Cerro de las Mesas on the Rio Blanco in the southern part of the state of Veracruz, on the Isthmus of Tehuantepec, and at the site of Izapa on the Mexican side of the Guatemalan border near the town of Tapachula. Of considerable interest was the report of the findings of the expedition, which included a cache of 782 jade objects and more than 30 stone monuments.

FREDERICK D. ROSSINI, *Secretary*.

Obituaries

HUGH MCCORMICK SMITH died early in the morning of September 28, 1941, of an attack of coronary thrombosis after an illness of only a few hours. He was 75 years of age, having been born on November 21, 1865, in Washington, D. C., son of Thomas Croggon and Cornelia Hazard Smith.

Smith began his natural-history studies when a small boy, owing largely to his father's interest in birds and other animals on his farm in Virginia. He was the first president of the Natural History Society of Central High School, D. C., from which he was graduated in 1884. In 1888 he was graduated in medicine, with a perfect record in all oral and written examinations, from Georgetown University Medical School and was a member of its staff from 1888 to 1905.

Dr. Smith's interest in science was influenced and probably guided while he was in high school by Spencer F. Baird, who in 1884–85 gave him the opportunity to work in the National Museum. He entered the service of the United States Fish Commission under Baird in 1886 and during the next six years had six promotions. He was co-special agent in charge of fisheries, United States Census of 1890. From 1893 to 1897 he was assistant in charge

of statistics and methods of the fisheries, United States Fish Commission, and during the next five years was assistant in charge, division of inquiry respecting food-fishes and the fishing grounds.

From 1903 to 1913 Dr. Smith was deputy commissioner of the Bureau of Fisheries, a position specially created by Congress, and from 1913 to 1922 he was the Commissioner of Fisheries. In 1900 he was named to represent the United States at the First International Fishery Congress, Paris; and again in 1905 at the Third International Fishery Congress at Vienna. He was secretary-general at the Fourth International Fishery Congress, Washington, in 1908.

Smith held several positions of honor, such as secretary, National Fishery Congress, 1898; chairman, International Jury on Fish Culture, Louisiana Purchase Exposition, 1904; expert adviser of the Food and Drugs Board and of the Bureau of Chemistry in fishery cases arising under the Pure Food and Drugs Act of 1906–13; expert special assistant of the United States Counsel at the Arbitration of the North Atlantic Fisheries Dispute at The Hague, 1910; United States Government representative of the International Commission for Adjudication of Fishery Disputes with Canada and Newfoundland arising under the award of The Hague arbitration tribunal, 1910; representative of the United States on the Permanent International Council for the Exploration of the Sea, 1912; member of the research committee and associate editor, National Geographic Society, 1909–19; commissioner on behalf of the United States on International Fishery Commission for regulation of fisheries in boundary waters of the United States and Canada, 1914. He was also director of the Marine Biological Laboratory of the United States Bureau of Fisheries, Woods Hole, Mass., 1901–02, and director of the *Albatross* expedition for investigation of fisheries and aquatic resources of the Philippine Islands, 1907–10.

From 1900 to 1934 he studied the aquatic resources and the fisheries, as well as inspected methods of fish culture, some of the laboratories, biological investigations, and fishery administrations, in 22 countries in Europe, South America, and Asia. The extensive collections made by Dr. Smith in these various lands and adjoining seas were given to various museums, but mostly to the United States National Museum.

This great naturalist was a member of no less than 15 scientific societies and contributed much to their advancement. He held the presidency for one or more years of the American Fisheries Society, the Biological Society of Washington, and the Cosmos Club of Washington, D. C. He was a fellow of the American Association for the Advancement of Science and honorary member of the following: Imperial Russian Society of Fish Culture and Fisheries, Imperial and Royal Austrian Fishery Society, and the Salmon and Trout Association of Great Britain and Ireland. In honor of his contributions to science, four birds, two reptiles, one amphibian, nine fishes, three mollusks, two crustaceans, two insects, and three other forms have been named for him. From 1898 to 1931 he was presented with seven honorary medals in recognition of his achievements and services.

Dr. Smith's chief contributions to science were in the fields of ichthyology and fisheries. In the latter field he spent 36 years with the United States Fish Commission, publishing about one hundred papers on fishery science; and a somewhat larger number on ichthyology have appeared under his name, describing numerous new species, new genera, and families of fishes. Among a total of about 300 published papers by him there is one or more in nearly all fields of natural history. Since 1925 his published researches were

largely on fishes and other animals from Siam, now Thailand, where from 1923 to 1935, as Adviser in Fisheries to his Siamese Majesty's Government, organizer of the Siamese fishery service and first director of the fishery bureau, he had ample opportunity to collect and study the fauna of that kingdom.

In addition to his official duties in Thailand he began collecting natural-history specimens in his spare time and sending them to the United States National Museum. In 1924 and again in 1926 he visited Koh Chang, a large mountainous island lying off the southeastern coast. On the mainland he covered all the territory fairly well from Patani in southern Peninsular Siam to the northern boundary and the eastern, southeastern, and southwestern parts of the country. Many of the localities were visited more than once and some several times. Although his chief interest while in Thailand was fishes, he sent 6,555 bird skins and bird skeletons to the United States National Museum besides thousands of other natural-history specimens. His interest in Siamese fishes was so great that upon his return to the United States in 1935 he began the most important scientific contribution of his life, "A Monograph of the Fresh-water Fishes of Siam." For the last six years this monumental work, with about 300 illustrations planned, occupied all his time in the division of fishes, United States National Museum, where he was associate curator in zoology. Although his untimely death left the Siamese manuscript not quite completed, it is being prepared for publication by one of his colleagues.

The death of Dr. Smith was a great shock to his family and to his numerous friends here and in many foreign countries. Through his death science has lost one of its great men. His kind nature and willingness to help students become established in their specialty made him dear to the hearts of many. To honor this great man, his friends had prepared to issue in November, 1941, an anniversary number of *Copeia* (the journal of the American Society of Ichthyologists and Herpetologists) on his 76th birthday, but much to the disappointment of all, this issue was published on November 21, 1941, as a memorial number. Dr. Leonhard Stejneger, in his tribute to Dr. Smith in this memorial issue of *Copeia*, has excellently summarized Smith's life:

"When Dr. Smith, in 1886, joined the U. S. Fish Commission the connection with the Smithsonian Institution, with Baird as the head of both, was in many respects so close that it sometimes was difficult to draw the line between them, and when in 1935 the Institution took Smith to its heart as Associate Curator of Zoology, he was practically at home again. As U. S. Commissioner of Fisheries Dr. Smith was Baird's worthiest successor, for he possessed in rich measure the same mental and spiritual qualities that inspired in all his associates, high and low, the respect, faith, admiration and love of which this note is only a feeble expression. In my heart two pictures stand side by side, Spencer Fullerton Baird and Hugh McCormick Smith; higher tribute I cannot conceive."

On March 12, 1889, Dr. Smith married Emma Hanford. Their daughters are Mrs. Edmund Vincent Cowdry, of St. Louis, and Mrs. Carl Harry Claudy, Jr., of Washington.

DAVID IVES BUSHNELL, JR., who died on June 4, 1941, enjoyed a notable career in American archaeology and ethnology. He was born in St. Louis, Mo., on April 28, 1875, and his future interests were no doubt determined in some measure by the fact that his father, a very successful business man, was long connected with the Missouri Historical Society and president of

a local body of archaeologists that conducted investigations in and about St. Louis. In the fall of 1899, during a canoe trip through northern Minnesota, young Bushnell witnessed a Chippewa ceremony and made some notes regarding it afterward included in an article in the *American Anthropologist*. The year following he accompanied Jacob V. Brower on an expedition to explore mound groups and village sites along the shores of Mille Lac. He kept a diary during this period the essential parts of which were incorporated in a memoir bearing the joint names of the participants.

From 1901 to 1904 Bushnell was an assistant in archeology at the Peabody Museum, Harvard University, made a study of aboriginal salt works at Kimmswick, Mo., and completed a report on the great Cahokia mound group. From 1904 to 1907 he was in Europe, visiting in particular England, Switzerland, and Italy, where he made notes regarding a number of collections of American Indian objects in various museums and engaged in some archeological work.

After his return to the United States he and his mother lived for a time at Charlottesville, Va., but later they moved to Washington, and he became a collaborator in the anthropological work of the Smithsonian Institution, contributing five bulletins to the publications of the Bureau of American Ethnology, thirteen papers to the Smithsonian Miscellaneous Collections, five to the Annual Reports, and one to the Proceedings of the National Museum, besides making several minor contributions. He was instrumental in obtaining a copy of the journal of Rudolph Friederich Kurz which was edited by J. N. B. Hewitt and printed as Bulletin 115 of the Bureau of American Ethnology. He contributed many papers to *Man*, the *American Anthropologist*, the *Journal of the Washington Academy of Sciences*, and various other scientific and historical periodicals.

In the winter of 1908–09 Bushnell made a study of a small group of Choctaw Indians living on Bayou Lacomb, La., but nearly all his later work consisted in archeological explorations in the neighborhood of Washington, though he made some collections on the Cape Fear River, N. C., and in Florida. In 1921 he visited Scott Field, the flying field east of Belleville, Ill., to obtain airplane pictures of the Cahokia mounds. The photographers were Lt. Harold R. Wells and Lt. Ashley C. McKinley. He was particularly interested in the soapstone quarries and projected a bulletin on the primitive salt industry of the American Indians, which he did not live to complete.

During all this time Bushnell was engaged in forming a collection of paintings and sketches of Indian subjects by early artists, some of them almost unknown either to ethnologists or historians. He projected a large work on artistic representations of Indians and Indian life in the period before 1875, but this undertaking also, for which he was supremely well prepared, was unfortunately cut off by his death.

Bushnell was possessed of a graceful style in writing. He exercised great care in the arrangement of his materials and was indefatigable in assembling the details for any work in which he was interested. His archeological investigations were generally confined to limited areas, but he opened up many interesting problems. In the attention that he called to certain European collections of Indian artifacts and in his assemblage of sketches illustrative of Indian life he performed a unique service and placed all American anthropologists in his debt.

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